DOCUMENT RESUME

ED 152 703 SP 012 327

AUTHOR Mertens, Donna M.; Bramble, William J.
TITLE Identifying Formal Level Functioning in Classroom Teachers.
PUB DATE Mar 78
NOTE 30p.; Paper presented at Annual Meeting, American Educational Research Association (Toronto, Canada, March 27-31, 1978)

EDRS PRICE MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS *Classroom Communication; Classroom Techniques; Cognitive Development; *Cognitive Style; Concept Formation; Educational Background; Logical Thinking; *Teacher Behavior; Teacher Characteristics; *Teaching Methods; *Thought Processes
IDENTIFIERS Piaget (Jean)

ABSTRACT

One aspect of Jean Piaget's theory of cognitive development was tested in this research project. It was hypothesized that an adult individual in the concrete stage of development is able to use seriation and classification in dealing with concrete objects, but is unable to think in terms of possibilities. An individual operating on the formal level of thinking, on the other hand, is able to generate the full range of possible solutions to a problem, reasoning systematically and using verbally stated propositions rather than concrete objects. The purpose of this research was to establish an empirical basis for the translation of Piaget's theory of formal operations into teacher classroom behavior and to determine whether teachers can distinguish between concrete and formal styles of teaching. A recognition task was developed that was designed to measure cognitive functioning in the educational domain. This was accomplished by designing two videotapes depicting teachers teaching the same subject: fire prevention. One teacher operated at the concrete level of thought, the other at the formal level. Seventy teachers viewed the videotapes and were asked to respond by describing observed teacher behaviors and rating the formal and concrete teachers on different characteristics. The subjects were also required to reply to questions designed to reveal how accurately they perceived the information presented in the videotapes, how fully they understood the more technical details of the presentation, and how much teaching experience each of them had. Preliminary results indicated that teachers may possess the underlying structures necessary for formal thought but their manifestion of formal thinking is perhaps dependent upon the subject matter in which they are tested. (JD)

Identifying Formal Level Functioning in Classroom Teachers

Donna M. Mertens and William J. Bramble

University of Kentucky

Paper presented at the 1978 meeting of the American Educational Research Association, Toronto, Session 29.05

Identifying Formal Level Functioning in Classroom Teachers

Donna M. Mertens & William J. Bramble

University of Kentucky

Piaget (1970a) described three main stages of cognitive development: (a) a sensorimotor period which lasts from birth to approximately 1 1/2 years of age, (b) preparation for and realization of concrete operations, the pre-operational period lasting from 1 1/2 or 2 to about 6, and the concrete period lasting from 7 to 11, and (c) the formal operational stage which begins around 11 or 12 and continues into adulthood.

As the sensorimotor and preoperational stages of development are not central to the present study, they will not be discussed further here. The characteristics of the concrete and formal stages are briefly described below. The individual in the concrete stage of development is able to use seriation and classification. However, these mental processes can be carried out only on concrete objects, i.e. the individual is unable to think in terms of possibilities. In Inhelder and Piaget's (1958) extensive description of formal level functioning, they described the individual in the formal operational stage as one who is able to derive possibilities (rather than actualities) by recombining the variables inherent in a problem. This individual is able to generate the full range of possible solutions to a problem. The formal reasoner is able to systematically reason in a hypothetical manner using verbally stated propositions rather than concrete objects.

Measurement of Formal Operations

Inhelder and Piaget (1958) used fifteen different tasks in their original research on formal operations that are described in The Growth of Logical Thinking from Childhood to Adolescence. A review of research replicationing Inhelder and Piaget's early work suggests that formal level functioning is not as common as is implied in their report (Mertens, 1977a). Table 1 provides a summary of research conducted to measure formal level functioning. The results range from 0% on the rings and correlations tasks to 67% on the pendulum, balance, and flexibility tasks.

Dulit (1972) explored the impression given by Inhelder and Piaget (1958) that formal stage thinking is the rule in adolescence. Dulit later learned that only adolescents at the fully formal level were included in the Inhelder and Piaget report because their purpose was to describe and to formulate the characteristics of the formal stage. Adolescents who failed to function at the formal stage were simply not reported. Dulit's study indicated that formal stage thinking is far from being commonplace among adolescents or adults. He concluded that it is a potentiality only partially attained by most and fully attained only by some.

Factors Influencing the Manifestation of Formal Operations

Piaget (1972a) suggested that a person who is not engaged in the physical sciences may manifest formal level functioning in his/her area of expertise, but not manifest formal level functioning on physical science oriented tasks. He recognized that it is highly likely that a person operating within his/her own field will know to reason in a hypothetical manner. He

Table 1

Summary of Research Measuring Formal Operations

Author	Task	Age	Percent Formal
Elkind 1961a	conservation of volume	11-12	27%
Elkind 1961b	conservation of volume	12-18	47%
Elkind 1962	conservation of volume	college students	58%
Graves 1972	conservation of volume	adults	24%
Karplus & Karplus 1970	paper and pencil task	science teachers	14%
		college physics teachers	40%
Tomlinson-Keasey 1972	pendulum, balance, and flexibility	11	32%
		19	67%
		54	57%
Juraschek 1974	equilibrium, probability, chemicals	preservice teachers	52%
Dilling, Wheatley, & Mitchell 1976	conservation of volume, separation of variables, equilibrium	university students, nonscience, education	32%
Smedslund 1963	correlations	student nurses	0%
Dulit 1972	rings	average IQ 14	0%
		average IQ 16-17	35%
		gifted 16-17	57%
		average IQ 20-55	33%
	chemicals	average IQ 14	10%
		average IQ 16-17	17%
		gifted 16-17	62%
		average IQ 20-55	25%

described the situation as: "They would, therefore, be capable of thinking formally in their particular field, whereas faced with our experimental situations, their lack of knowledge or the fact they have forgotten certain ideas that are particularly familiar to children still in school or college, would hinder them from reasoning in a formal way, and they would give the appearance of being at the concrete level" (p. 10). He further stated that aptitude and vital interest appear to be important factors in the manifestation of formal operations.

Elkind (1975) concurred with Piaget's position, and yet he recognized difficulties inherent within it. Elkind's remarks highlight the problems with testing subjects in their particular domain of expertise. He stated:

> "Piaget's suggestion (1972a) that people be tested in formal operations in their area of specialization seems reasonable in principle but difficult to achieve in practice. How does a salesman, a shoe clerk, or a carpenter use formal operations? To be sure, some areas of specialization may require formal operational thinking, but not all occupations do. Devising tests of formal operations for specific fields is a difficult task but one that has to be attempted if the questions of the generality or universality of formal operations is to be answered" (p.53).

The problem of testing people in their own domain of expertise arises partially because Inhelder and Piaget used performance on physical science oriented tasks to describe typical formal level functioning.

Blasi and Hoeffel (1974) addressed the problem that arises in trying to translate Piaget's description of formal level functioning into "social behavior". Because formal operations tasks were derived from physics, the kind of possibility involved is perhaps limited to the possibility of derivations from physical premises. The equilibrium properties of physical systems may not be found outside the domain of physics.

There are other types of possibility that do not seem to fit the concept of physical possibility. Psychological or subjective possibility is different from physical possibility because it is difficult to understand psychological factors like obedience or love as an effect of balanced and unbalanced factors. Psychological possibility is not derived from rigidly compensated systems. Blasi and Hoeffel suggest that this difference between physical and psychological possibility provides a basis for questioning the necessity of formal operations for adolescent personality development.

In Flavell's (1970) reflections on cognitive changes in adulthood, he discussed the fact that biological constraints do not operate as strongly in adult cognitive development as they do in childhood, and therefore, that experience plays a larger role in adult development. He recognized occupational activities as important sources of change in adults. He further stated that most adult cognitive changes probably involve constructing implicit models of the social-personal world rather than the logical-natural world.

The relationship between the manifestation of formal operations and other factors have been investigated by a number of researchers. Flavell (1971) recognized the distinction between performance and recognition tasks as an influential factor. He pointed out that production requires both evocation of the cognitive operation necessary for solution of the task, and utilization of the operation to solve the task. A recognition task requires only a minimal level of representation, and therefore might be more sensitive for facilitating the manifestation of cognitive operations.

Pilot work conducted by Martorano (1976) supports the hypothesis that a recognition task is a more sensitive measure of cognitive operations.

Role of Teacher Based on Piaget's Theory

Descriptions of the educational implications of Piaget's theory provide insight into a teacher's domain of expertise from a Piagetian perspective (Furth, 1970; Kamii, 1973a, 1973b; Piaget, 1970b, 1972b; Schwebel & Raph, 1973; Wickins, 1973). Based on these descriptions, Mertens (1977a) derived a conceptual correspondence between formal level functioning and teacher classroom behavior (see Table 2).

Purpose

The purpose of the present research is twofold: 1) to establish an empirical basis for the translation of Piaget's theory of formal operations into teacher classroom behavior, and 2) to determine whether teachers can distinguish between concrete and formal styles of teaching.

Problems

The specific problems addressed in this research are as follows:

1. What are the characteristics of a teacher who functions at the formal level?

2. Can teachers recognize a difference between formal and concrete teaching strategies?

3. What influence do selected background characteristics have on teachers' abilities to discriminate between formal and concrete teaching strategies and their abilities to score at a formal level on a standard Piagetian task?

Table 2

Formal Operations and Teacher Behaviors

Formal Operations	Teacher Behaviors
Thinking of the possible vs. the real	Able to make inferences about covert social-psychological processes
Generation of all possible solutions	Construe social behavior in a multidimensional way
Isolation of variables	Recognition of more possibilities to explain behavior
Derivation of possibilities by recombining the variables inherent in a problem	Postulating alternative interactive strategies
Deduction of potential relationships	Suggesting hypothetical relationships between variables
Able to adopt other's point of view, logically deduce consequences, judge its value	Able to adopt other's point of view, manifested by accepting and using student's ideas and feelings, encouraging student talk, and openness to the ideas of other professionals
Emphasis on active learning	Active learning, including providing an opportunity for student talk and question asking, less lecturing, compelling reflection, and providing opportunity for experimentation

4. Do teachers who are able to recognize differences between formal and concrete teaching strategies also score at a formal level on a paper and pencil version of a standard Piagetian task?

5. What insight does the relationship between performance on an educational task and on a standard Piagetian task give into performance-competence, horizontal decalage, cognitive development in adults, and formal level functioning in teachers?

Methodology

In the present study, a recognition task was developed which was designed to measure cognitive functioning in the educational domain. This was accomplished by designing two videotapes depicting teachers teaching the same subject: fire prevention. Each tape was based on a conceptual correspondence between Piaget's descriptions of formal and concrete functioning and teacher classroom behavior. Descriptions of the videotapes are presented in Table 3.

The subjects were 22 male and 48 female teachers, 61 of whom were enrolled in summer school classes and 9 of whom were attending an inservice training workshop. The design was a quasi-experimental equivalent materials design described by Campbell and Stanley (1966). The independent variables were group (five summer school classes and one inservice training group) and videotape (formal vs. concrete).

The procedures consisted of having the subjects watch both videotapes and then asking them to react to the videotapes and to complete the following five dependent measures:

Table 3

Contrasting Formal and Concrete Approaches to Teaching in Videotapes

Formal Teacher

This teacher introduced the topic of fire prevention from the perspective of the "possible" rather than the "real". This ability to think in terms of possibilities is one characteristic of formal thinking. She also used categories from the outset of the lesson to effectively structure the generation of many possible items.

When a disruption occurred in the classroom, the teacher explored alternative explanations for the disruption. She was able to recognize both of the students' points of view. She then helped the disruptive student explore alternative behaviors for resolving the problem.

When the student did not understand an idea, the teacher explored alternative teaching strategies to explain the subject. Formal operations is exhibited here because the teacher is flexible and is able to think of and try out several different approaches to making the same point.

In the last part of the lesson, the teacher used a combinatorial system to organize the learning activities. The ability to construct a combinatorial system means that a person can think of all the possible combinations of variables in a given problem. Her use of this combinatorial system resulted in teaching the students the rules for thinking about fire hazards and how to prevent fires.

Table 3 -- continued

Concrete Teacher

This teacher began the lesson by using concrete examples. Throughout the lesson, she encouraged the students to respond with other concrete examples. The focus was on the real rather than the possible.

In the classroom disruption scene, the teacher automatically interpreted the situation as she saw it, without exploring alternative causes for the disruptive behavior. She handled the situation by evoking a rule which was supposed to cover situations of this type.

The teacher did not use categories to structure the first portion of the lesson, therefore, the students' responses were somewhat haphazard. There was no systematic generation of possibilities within categories.

When the student said that he did not understand an idea, the teacher simply reiterated what was already said, suggesting that if the same thing is repeated, the student will understand. She then presented information that was similar to that presented by the formal teacher, but she did not use this as an alternative teaching strategy.

She did introduce categories toward the end of the lesson. The fire prevention techniques were discussed within categories, but all of the possibilities for fire prevention were not explored.

1. Description. This instrument provided the subjects with a relatively unstructured format for noting the characteristics of the two teachers in the videotapes.
2. Characteristics of Teachers (CT). This instrument was designed to determine whether specific attributes of the teachers were biasing and whether the subjects accurately perceived the information presented in the videotapes.
3. Comparing Teacher Performance (CTP). This instrument provided the subjects with an opportunity to rate the formal and concrete teachers on six differentiating characteristics and to directly compare them on three characteristics.
4. Preventing Chemical Explosions (PCE). This instrument is a paper and pencil analogue of Inhelder and Piaget's (1958) chemicals task which was rewritten as a problem in fire prevention.
5. Confidential Background Questionnaire (CBQ). This instrument was designed to ascertain demographic data and information concerning the subjects' teaching experience.

A validity study using experts in Piagetian theory as subjects and a pilot study using undergraduate students as subjects were conducted in order to provide validity and reliability data for the videotapes and instruments used in the present study (Mertens, 1977b). The reliabilities ranged from .7034 to .2109. These were considered to be acceptable because of the relationship between reliability and the likelihood of making a Type I or Type II error and the power of the test.

Results and Discussion

The purpose of this section is to provide answers to the five research questions which were presented earlier in this paper. A discussion of the limitations and implications of this study is also included.

What are the characteristics of a teacher who functions at the formal level?

The results of this study provided empirical support for the conceptual correspondence between Piaget's theory and teacher classroom behavior.

The results of a factor analysis of the pilot group's response on the CTP scale indicated three factors (Mertens, 1977b). The first, named "Competency", referred to the teacher's competency in the subject matter. The second, named "Strategies" included the ability to see the student's point of view, the ability to explore alternative behaviors for settling a discipline problem, the ability to help students systematically explore multiple possibilities of the subject matter, and the ability to use alternative teaching strategies to explain a point when a student did not understand. The third factor, named "Organization", referred to the ability to use categories effectively to structure the lesson.

These results based on expert ratings and teacher sample ratings substantiate the conceptual correspondence between teacher classroom behavior and Piaget's notion of formal operations which was presented earlier. The formal teacher is one who is able to see the student's point of view, explore multiple possibilities of a subject, and explore alternative teaching strategies. This person is also able to organize material systematically by using categories effectively.

Can teachers recognize a difference between formal and concrete teaching strategies?

The results of the subjects' performance on the Description, CT, and CTP scales indicate that they were able to recognize the difference between the formal and concrete teaching strategies. The subjects' descriptions of the concrete and formal teachers focused on critical aspects of formal level teaching.

On the CT scale, the subjects were able to differentiate between the formal and concrete teachers on key variables concerning formal functioning. The majority of their responses indicated that personal attributes were not a biasing factor and that they understood and remembered the content of the tapes. The major limitations for the interpretation of the results, as indicated by the subjects' responses on this instrument, was the perception of the concrete teacher as being punitive.

The results of the CTP scale were analyzed using a 6 x 2 design with six groups and two videotapes (the videotape ratings were a repeated measure of the same variables). The dependent measures were the three factor scores discussed above. The results of this analysis are presented in Table 4. No between subject group effects were significant (multivariate $F = .75$, $p < .73$). Significant multivariate effects for Videotape (multivariate $F = 66.12$, $p < .0001$) and Videotape by Group (multivariate $F = 1.96$, $p < .03$) were found.

The univariate and step-down F's presented in Table 5 indicate where the differences occurred. The Videotape by Group differences occurred only on the Strategies variable. The means for the six groups on the Strategies

Table 4

MANOVA of Group by Videotape (with Repeated Measures on Videotape) for Teacher Sample

Source	Multivariate	d.f	p
Between Subjects			
Group (G)	.75	15,172	.73
Within Subjects			
Videotape (V)	66.12	3,62	.0001
V x G	1.96	15,172	.03

variable are displayed in Figure 1. All of the groups followed a similar pattern except Group 3. This group did not differentiate as much between the formal and concrete teachers as the other groups. Based on the subjects' comments during the debriefing session, this lack of differentiation may be the result of the class's philosophical orientation. Several subjects commented that both teachers used a traditional discussion format during the lesson. They indicated that they had expected the formal teacher to employ more nontraditional techniques such as a field trip or experimentation with flammable materials.

The Videotape differences occurred on all three dependent variables: Competency, Strategies, and Organization, thus indicating that teacher-subjects can recognize a difference between formal and concrete teaching strategies.

The fact that the videotape task involved recognition and not performance limits the interpretation of these results. As Flavell (1971)

Table 5

Univariate and Step-Down F's for Repeated Measures Analysis for Teacher Sample

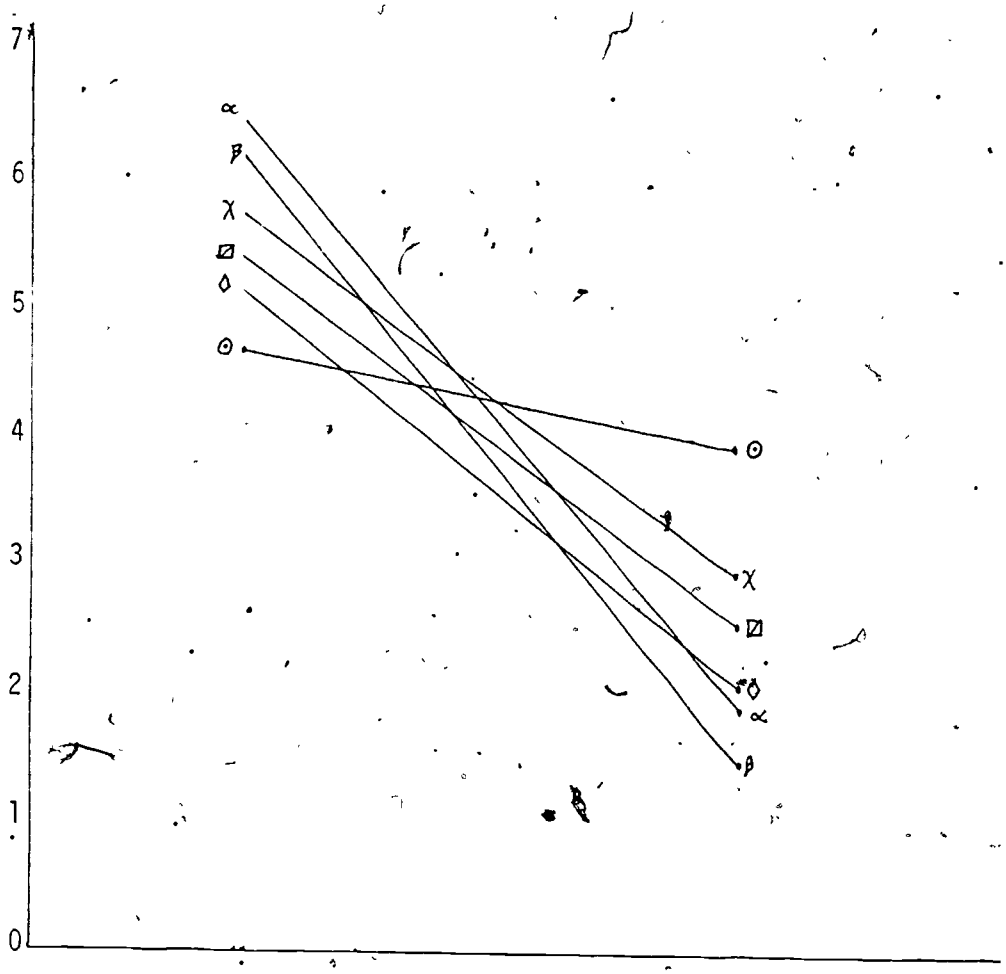
Source	d.f.	M.S.	Univariate F	p	Step-Down F	p
Between Subjects	70					
Group (G)	5					
Competency		.53	.52	.76	.52	.76
Strategies		.21	.50	.78	.43	.82
Organization		.70	1.28	.28	1.34	.26
Error Between	64					
Competency		1.03				
Strategies		.41				
Categories		.55				
Within Subjects	70					
Videotape (V)	1					
Competency		41.66	72.57	.0001	72.57	.0001
Strategies		136.85	92.01	.0001	20.06	.0001
Organization		163.56	135.16	.0001	30.54	.0001
V x G	5					
Competency		.22	.39	.86	.39	.86
Strategies		3.85	2.59	.034	3.71	.006
Organization		2.60	2.15	.07	2.00	.09

Table 5 -- continued

Source	d.f.	M.S.	Univariate F	p	Step-Down F	p
Error Within	64					
Competency		.57				
Strategies		1.49				
Organization		1.21				

Figure 1

Group by Videotape Interaction for Strategies Variable



Formal

Re-Ed Group

Group 1

Group 2

Concrete

Group 3

Group 4

Group 5

pointed out, a person may be able to recognize appropriate behavior for solving a problem, but be unable to perform a task because of the difficulty involved in applying the recognized principles. He stated, "....utilization difficulties would likely figure much more prominently in the case of more complex intellectual items, as, for instance, the role-taking skills and Piagetian operations..." (p. 430). Thus, it cannot be inferred that the ability to recognize formal level teaching behaviors implies an ability to perform at a formal level in the classroom. However, since recognition is a necessary prerequisite to performance, the ability to recognize such a difference implies at least a rudimentary development of the operations necessary for performance. Further insights into the relationship between recognition and performance await continued research.

What influence do selected background characteristics have on the teachers' abilities to discriminate between formal and concrete teaching strategies and their abilities to score at a formal level on a standard Piagetian task?

A multivariate regression analysis was performed with the Competency, Strategies and Organization variables. The regression variables included years of teaching experience, undergraduate hours completed in education, subject matter taught (science and mathematics vs. non-science and mathematics), undergraduate hours completed in science and mathematics, grade level taught (elementary, junior high, senior high, and college), sex, age, and highest degree completed (bachelor's, master's, and doctorate). The results of this analysis are presented in Table 6. None of the regression variables were significantly related to the dependent variables, thus suggesting that background characteristics show no relationship with the ability to discriminate between formal and concrete teachers.

Table 6

Regression Analysis for Competency, Strategies and Organization Variables for Teacher Sample

Dependent Variable	Squared Multiple R	Multiple R	F	p	Step-Down F	p
Competency	.12	.34	.94	.49	.94	.49
Strategies	.13	.35	1.01	.44	.98	.46
Organization	.05	.22	.36	.94	.34	.94

Multivariate F = .7371, df = 24,157, p <.81

A multivariate regression analysis was also performed on the Comparison (items 13, 14 and 15 of the (TP) and Chemicals variables with the same regression variables used in the previous analysis. These results are presented in Table 7. The regression analysis indicated no significant relationship between the background characteristics and performance on either the judgment or the chemical tasks.

Table 7

Regression Analysis for Background Variables and Chemicals and Comparison Variables for Teacher Sample

Source	Squared Multiple R	Multiple R	F	p	Step-Down F	p
Comparison	.19	.44	1.30	.27	1.30	.27
Chemicals	.21	.46	.50	.19	1.49	.19

Multivariate F = 1.38, df = 16,86, p <.17

Whether background variables do influence performance on the CTP and PCE scales is not unequivocally answered by the results of this study. It is possible that the groups were too homogeneous, the instruments were not sensitive enough, or the ease or difficulty of the tasks interfered. Future research is necessary to further clarify this issue.

Do teachers who are able to recognize differences between formal and concrete teaching strategies also score at a formal level on a paper and pencil version of Piaget's chemicals task?

The answer to this question is no. The teachers were able to discriminate between the concrete and formal teaching strategies. The majority of them were not able to score at the formal level on the paper and pencil version of Piaget's chemicals task.

This task was scored using a 5-point scale, with 1 indicating a preoperational response and 5 indicating a late formal response. The subjects had an average score of 2.59, or between an early and late concrete level of performance. Few of the subjects were able to go beyond a combination of n + 1 variables. The comments made by the subjects indicated that motivation may be an important variable in the ability to perform the chemicals task.

Within the limitations of this study, as noted above, these results support Piaget's contention that adults may not manifest formal operations in the experimental situations used by him and Inhelder, and yet be able to think formally in their particular field. This study also supports Sinnot's (1975) findings that adults may be able to manifest formal operations when tested with familiar materials, but be unable to do so when traditional Piagetian materials are used.

Elkind (1975) and Dulit (1972) both remarked that all persons may not be required to operate at a formal level to perform their occupations. Another question which still remains to be answered is whether teachers are rewarded for employing concrete or formal teaching strategies in their classrooms.

If future research can devise performance tasks for teachers, the results will yield additional insight into the seeming lack of formal operations found by other researchers (Dilling, Wheatley, & Mitchell, 1976; Dulit, 1972; Elkind, 1961a, 1961b, 1962; Graves, 1972; Juraschek, 1974; Karplus & Karplus, 1970; Tomlinson-Keasey, 1972).

What insight does the relationship between performance on an educational task and on a standard Piagetian task give into performance-competence, horizontal décalage, cognitive development in adults, and formal level functioning in adults?

Flavell and Wohlwill (1969) distinguished between performance and competence. Competence referred to the existence of the underlying structures necessary for operational thought. Performance referred to the psychological processes involved in manifesting formal thinking in a particular setting. These results of the present study indicate that teachers may possess the underlying structures necessary for formal thought, but their manifestation of formal thinking is perhaps dependent upon the subject matter in which they are tested. For the most part, they were unable to perform at a formal level on the chemicals task, yet they were able to recognize a difference between formal and concrete functioning in the educational problem. Further and more definitive

implications for the performance-competence model await future research.

Pinard and Laurendeau (1969) discussed Piaget's notion of horizontal decalage. Essentially, they stated that horizontal decalage involved the chronological difference between the ages of acquisition of operations that bear on different concepts (or contents) but obey identical structural laws. The development of the structures for formal operations may have occurred in this sample of adult teachers. They are able to apply these structures in a recognition task in an educational setting, yet they are unable to apply the identical structures in solving a chemicals task. As Flavell (1970) noted, chronological age differences become less important and differences in life experiences become more important during adult development. It may be that in adulthood, a horizontal decalage would continue to exist for many content areas, because an adult's range of experiences can vary greatly.

This study does suggest that Piaget's theory of formal development has the potential to explain cognitive development in adulthood, if the critical factor of domain of expertise is taken into account. For many adults, the skills necessary for combining chemicals or for understanding the workings of a hydraulic press, are unnecessary for successful survival in their day-to-day world. It may be that formal thinking in the social domain is a necessary stage in development for successful operation in the person-oriented professions, such as teaching. As Blasi and Hoeffel (1974), pointed out, this translation of formal functioning into the social domain is a difficult task. But, as is indicated in this study, it may prove valuable for further understanding of adult development.

Probably the most significant contribution of this study is the insight it provides into formal level functioning in teachers. The study provides an empirical basis for applying Piaget's theory to teacher classroom behavior. The conceptual structure presented in Table 1 was supported by the empirical data collected in the study. This structure can provide the basis for developing performance tasks in the area of education. Research with performance tasks would provide more definitive answers to the questions that were explored in this study, as well as generate additional questions of interest.

Bibliography

Blasi, A., & Hoeffel, E. C. Adolescence and formal operations. Human Development, 1974, 17(5), 344-363.

Campbell, D. T., & Stanley, J. C. Experimental and quasi-experimental designs. Chicago: Rand McNally, 1966.

Dilling, R. A., Wheatley, G. H., & Mitchell, R. An EEG investigation of the differences in the hemispheric specialization of formal and concrete operational persons. Paper presented at the annual meeting of the American Educational Research Association, San Francisco, 1976.

Dulit, E. Adolescent thinking à la Piaget: The formal stage. Journal of Youth and Adolescence, 1972, 1, 281-301.

Elkind, D. Children's discovery of the conservation of mass, weight, and volume. Journal of Genetic Psychology, 1961, 98, 219-227. (a)

Elkind, D. Quantity conceptions in junior and senior high school students. Child Development, 1961, 32, 551-560. (b)

Elkind, D. Quantity conceptions in college students. Journal of Social Psychology, 1962, 57, 459-465.

Elkind, D. Recent research on cognitive development in adolescence. In S.E. Dragastin & G. H. Elder (Eds.), Adolescence in the life cycle. Washington, D.C.: Hemisphere, 1975.

Flavell, J. Cognitive changes in adulthood. In L. R. Goulet & P. B. Baltes (Eds.), Life-span developmental psychology: Theory and research. New York: Academic Press, 1970.

Flavell, J. H., & Wohlwill, J. F. Formal and functional aspects of cognitive development. In D. Elkind & J. H. Flavell (Eds.), Studies in cognitive development. New York: Oxford University Press, 1969.

Furth, H. G. Piaget for teachers. Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1970.

Graves, A. J. Attainment of conservation of mass, weight, and volume in minimally educated adults. Developmental Psychology, 1972, 7, 223.

Inhelder, B., & Piaget, J. The growth of logical thinking from childhood to adolescence. New York: Basic Books, 1958.

Juraschek, W. A. Piagetian cognitive development among prospective teachers. Technical Report No. 4. Austin, Texas, Texas University, Mathematics Education Center, 1974. (ERIC Document Reproduction Service No. ED 106 122)

Kamii, C. Pedagogical principles derived from Piaget's theory: Relevance for educational practice. In M. Schwebel & J. Raph (Eds.), Piaget in the classroom. New York: Basic Books, 1973. (a)

Kamii, C. Piaget's interactionism and the process of teaching young children. In M. Schwebel & J. Raph (Eds.), Piaget in the classroom. New York: Basic Books, 1973. (b)

Karplus, E. F., & Karplus, R. Intellectual development beyond elementary school: Deductive logic. School Science Mathematics, 1970, 70(5) 398-407.

Martorano, S. C. A recognition measure of formal operations thinking. Unpublished manuscript, University of Kentucky, 1976.

Mertens, D. M. Formal level functioning: A scientific phenomenon? Paper presented at the 1977 Annual Meeting of the American Educational Research Association, New York. (ERIC Document Reproduction Services No. ED 137 579) (a)

Mertens, D. M. Identifying concrete and formal level functioning in classroom teachers. Unpublished doctoral dissertation, University of Kentucky, 1977. (b)

Piaget, J. Piaget's theory. In P. H. Mussen (Ed.), Carmichael's manual of child psychology. New York: John Wiley, 1970. (a)

Piaget, J. The science of education and the psychology of the child. New York: Orion Press, 1970. (b)

Piaget, J. Intellectual evolution from adolescence to adulthood. Human Development, 1972, 15, 1-12. (a)

Piaget, J. To understand is to invent. New York: Grossman Publishers, 1972. (b)

Pinard, A., & Laurendeau, M. "Stage" in Piaget's cognitive-developmental theory: Exegesis of a concept. In D. Elkind & J. H. Flavell (Eds.), Studies in cognitive development. New York: Oxford University Press, 1969.

Schwebel, M., & Raph, J. The developing teacher. In M. Schwebel & J. Raph (Eds.), Piaget in the classroom. New York: Basic Books, 1973.

Sinnott, J. D. Everyday thinking and Piagetian operativity in adults. Human Development, 1975, 18, 430-443.

Smedslund, J. The concept of correlation in adults. Scandinavian Journal of Psychology, 1963, 4, 165-173.

Tomlinson-Keasey, C. Formal operations in females from eleven to fifty-four years of age. Developmental Psychology, 1972, 6, 364.

Wickins, D. Piagetian theory as a model for open systems of education. In M. Schwebel & J. Raph (Eds.), Piaget in the classroom. New York: Basic Books, 1973.